TEACHER EDUCATION

Graduate Students Study

Educational Problems

I

DECEMBER, 1959

ILLINOIS STATE NORMAL UNIVERSITY

NORMAL, ILLINOIS

FOREWORD

Graduate work at Illinois State Normal University was authorized in 1943 and actually begun in the summer of 1944. In the next year the policy of publishing short abstracts of theses was begun by the University. Such abstracts now appear annually in the November *Bulletin*. In recent years the Editorial Committee came to the conclusion that a limited number of theses should be given more extensive treatment. To implement this decision, the Committee solicited two article-length abstracts of theses from several departments of the University. This number of *Teacher Education* contains abstracts of theses prepared by graduate students in the departments of Mathematics, Natural Science, and Biological Science. These longer abstracts from the remaining departments will be published in future December numbers of this publication.

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THE USE OF PROJECTS IN THE TEACHING OF HIGH SCHOOL CHEMISTRY

ROBERT L. CRAMER

Traditionally, the primary function of a course in high-school chemistry has been to prepare students for advanced work in college chemistry. In recent years, however, there has been a persistent demand upon chemistry teachers to consider and assume another important function, namely, instruction for general education. A committee of the Progressive Education Association has stated the aims of general education as follows:

> The purpose of general education is to meet the needs of individuals in the basic aspects of living in such a way as to promote the fullest possible realization of personal potentialities and the most effective participation in a democratic society.[1]

Largely due to the progress in science, our society is becoming increasingly complex. Problems of enormous magnitude are being created, such as the production and control of atomic power and conservation and utilization of natural resources. A knowledge of chemistry can aid materially in the solution of these problems and thus help much in shaping the intellectual life of our society.

Purposes of the Study

The purposes of this study were to show that:

1. Students will develop a greater interest in chemistry through the use of chemistry projects.
2. The project plan is a sound method of meeting individual differences.
3. Opportunities for creative ability and original thought will be developed to a greater degree than with the traditional method alone.
4. The ability to use the scientific method will be developed to a greater degree through the use of the project method.
5. Students will become acquainted with much equipment that they would never use in the traditional method.
6. Students will develop a greater ability for preparing normal, molar, and percentage solutions.
7. Projects can serve as excellent teaching aids for the instructor.
8. Projects may grow into hobbies for using one's leisure time.
9. The use of projects encourages students to participate in the Annual Science Talent Search.

[1] The Progressive Education Association. *Science in General Education* (New York: D. Appleton-Century Company, 1938), p. 23.

Source of Data

The information included in this study was obtained in the following manner: by securing descriptions of projects from teachers who had students that entered projects at the state meeting of the Illinois Junior Academy of Science, by reading literature concerning chemistry projects, by writing to industrial concerns for procedures about specific projects, and by having the students actually do the projects.

The laboratory manual *Test It Yourself by* Tuleen, Muehl, and *Porter* [2] was found to be an excellent source of projects. *Chemistry*

The periodicals *Journal of Chemical Education, School Science and Mathematics,* and *Science Teacher* were other valuable sources of chemistry projects.

Value of Projects

The value of projects in the teaching of high school chemistry is given in a discussion by Otto J. Walrath. He states:

> In 1943-1944 we decided to require a project from every student in our chemistry classes. It was successful. Between 250 and 300 projects were turned in . . . . Many of these were so outstanding we were asked to set up an exhibit in our cafeteria, so that all the pupils in the school could see what we were doing in chemistry. . . .
>
> In 1944-1945, we became more ambitious. We decided to require a project from every student in the science department including chemistry, physics, and biology. . . .
>
> We plan to continue requiring a project from all our science students. We are sold on the idea. The pupils like it, the parents approve, we get valuable teaching aids, the teachers are enthusiastic and, as one of the youngsters said, "when you make a project you surely know the process by heart.[4]

The conventional high school chemistry course should be altered so as to provide the students with a practical knowledge of chemistry which will enable them to better appreciate and adapt themselves to their environment. A course in chemistry should include subject matter which is considered essential to an understanding of chemistry and should make adequate provision for supplementary material which would be of value to the students in later life. In recent developments in the field of psychology it has been shown that students learn best if they are actively and wholeheartedly engaged in some purposeful activity. The use of projects as a supplement to the traditional chem-

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[2] Lawrence F. Tuleen, Willard L. Muehl, and George S. Porter, *Test It Yourself* (Chicago: Scott, Foresman and Company, 1953), 1.

Projects, by John C. Chiddix,[3] was also an outstanding manual.

[3] John C. Chiddix, *Chemistry Projects* (Normal, Illinois: Science Publications, 1949), 1.

[4] Otto J. Walrath, "An Experiment in Adolescent Ingenuity," *School Science and Mathematics,* XLVI (May, 1946), 469-471.

istry program provides one way of furnishing the right kind of purposeful activity.

E. B. Chrisman states:

> The project method, while presenting many undesirable features if over-used, offers one of the richest sources of stimulation that can be found for second semester chemistry. Twenty-four weeks of basic instruction, followed by six weeks project work affords variety, offers a real challenge to the student, and provides one of the richest periods of the entire course.[5]

It was interesting to note the reactions of students in both the traditional and the project methods. In many instances in the traditional plan the students went to the laboratory knowing in advance what was going to happen. However, in doing projects students seemed to enjoy finding the answers for themselves. Projects gave them a sense of confidence that was not attained in the traditional method. Students asked for more time in the laboratory. Besides the time spent in the regular laboratory session the students worked in the laboratory in the morning before classes, during their free periods, and after school had been dismissed for the day. It was not uncommon to have students ask for permission to work in the laboratory for one or two evenings a week.

Projects aid materially in meeting individual differences. The chemistry classes of a large number of high schools consist of students with a wide range of interests and abilities. This situation in any one chemistry class demands considerable attention in order to insure continuous growth for all pupils. Since no two pupils are alike in interests, abilities, or rates of learning, no single body of subject matter is very likely to meet the needs of all. Provisions for a wide range of learning activities, representing different degrees of ability, should provide the most satisfactory approach to this problem of differences among students. In the project plan the teacher has an opportunity to spend more time with individual pupils and, therefore, to stimulate them to further effort. Those pupils who would be hopelessly behind in a traditional class can work at their own speed and acquire that important feeling of success. Students who would normally be held back by the slower pupils may, too, work at their own speed to higher levels of achievement.

Herman O. Hoode states:

> The simple activities of a "project" also lead into more complex and worthwhile activities which develop the individual greatly. In the use of the project for a period of years it has become apparent that such activity will lead many pupils into other activities which reach a higher level of understanding

[5] E. B. Chrisman, "Two Years with Chemistry Projects," *School Science and Mathematics*, XXXIX (February, 1939), 162.

> and appreciation. . . . Many of them entered the science courses with fear and doubt as to their success, having heard of the difficulties to be expected. If the course had been taught from the standpoint of strict knowledge and rigid "mental discipline" one of three things would have occurred: 1, those people would have dropped the course in a short time, 2, enrollment would have declined as that group turned to other courses, or 3, failure, with its bad effects on pupil and community. The project method eliminated these choices for the less able student, referring to ability as scholastic success, and allowed, at the same time, for a program of activities in the class for those who were able to do, and could profit by, intensive work. Thus all levels of ability were served.[6]

To secure a more intelligent appreciation of what science and technology have done for progress in our society students must be taught to use scientific facts and observations in reaching a conclusion. The development of this ability becomes of utmost importance when one attempts to observe and decipher the many unsolved social and economic problems that exist in the world today. The teaching of chemistry affords an excellent opportunity for the development of this method of thinking. However, chemistry will have to be taught in such a manner that pupils can be trained in its use. Projects present a good opportunity for an appreciation and understanding of the scientific method of reasoning. Since the recognition of the problem is the first step in this method of learning, students must be given the opportunity to propose problems for study. Ready-made problems are not presented to the students, but rather situations involving problems that are utilized in teaching students to recognize and define problems. In developing this ability the teacher must not depend solely on a single text as the only instrument of learning. Students must read extensively in other books and periodicals as well as their own texts. One observing the teaching of chemistry in many public schools of today must be impressed with the emphasis that is placed on the memorization of facts and the lack of emphasis on teaching the students how to think for themselves. In the traditional laboratory plan students verify facts that are already known and they receive, if any, very little training in the use of the scientific method. In many cases the subject of the experiment carries with it little interest or motivation for the students; consequently, they blindly follow directions with little questioning or understanding.

Projects, if properly done, can do much in developing the originality of students. In a great number of instances projects suggested by the students will require the establishment of procedures and research into methods of carrying on the experiments. Originality in arranging the materials for display, aptitude for collecting facts dur-

[6] Herman O. Hoode, "A Defense of the Project Method," *School Science and Mathematics*, XLIX (October, 1949), 560.

ing observation, and skill in arranging and manipulating laboratory equipment are called into play by the students during the planning and execution of the projects.

Because of the highly technical and mechanized nature of our society we are finding that the youth of today possess a tremendous amount of unoccupied time. This fact creates a growing problem for the educator in trying to provide training in purposeful leisure time activities which can be carried over into adult life. The use of projects in chemistry can do much in the development of hobbies which can be of great value in the worthy use of leisure time. Some of the associations between projects and hobbies may be found in such activities as photography, soil testing, glass and metal etching, electroplating metallic and nonmetallic articles, and the silvering of mirrors. One can often teach a great deal more chemistry through a hobby than through a textbook.

Through the use of projects students are actively engaging in some purposeful activity. They are allowed to make their own solutions and to determine, by means of weight-weight and weight-volume problems, the quantity of given chemicals needed for their projects. Students can be told how to prepare normal, molar, and percentage solutions, but they learn best through their actual preparation of the solutions.

Methods Used in Teaching

Before projects on some phase of chemistry were attempted the writer was of the opinion that students should be acquainted with the basic fundamentals of chemistry. A committee on the correlation of high school with college chemistry had prepared an outline of elementary chemistry which was intended to meet the needs of both the students who entered college and those who went directly into the active affairs of life. The following essential topics were considered vital in all elementary courses of high school chemistry.[7]

1. Introduction to Chemistry
2. Water and Solution
3. Chemical Changes, Elements, Compounds, and Mixtures
4. Electrical Structure of Matter
5. Symbols, Equation, Weight Relations, and Volume Relations
6. Periodic Classification of Elements—including a study of the halogen group to show the meaning of group relations.
7. Acids, Bases, Salts, and Ionization
8. The Nature af Non-Metallic Elements—including the general occurrence, preparation, and general properties of some typical non-metallic elements.
9. Carbon, Carbon Dioxide, and Carbon Monoxide
10. The Nature of Metallic Elements—including the occurrence, methods of extraction, and action of air, water, and dilute acids on a few typical metallic elements.

[7] B. S. Hopkins *et. al.*, "An Outline for Essential for a Year of High School Chemistry," *Journal of Chemical Education*, XIII (April, 1936), 175-179.

11. Organic Chemistry—including the characteristic organization of carbon compounds, hydrocarbons, alcohols, organic acids, esters, carbohydrates, foods and miscellaneous organic compounds.

At the beginning of the second semester the students were given information concerning the value and sources of projects, ways of exhibiting them, and any other suggestions that might stir up an interest in the project method. A list of some forty or fifty topics, with enough description to give "leads" concerning the projects, were posted on the bulletin board. The writer made certain that the projects were workable. Some students found it necessary to visit university libraries for information that was not available in the high school or city libraries. The availability of periodicals and books was probably one of the factors most difficult to work with in the project plan. This was most important because students needed to do extensive reading in the fields of their interests before the selection of a project. It was found in this study that some students required more time than others. This was a critical period because many were unaccustomed to the freedom and responsibility of selecting what they should learn, and it was only natural that they might turn to the teacher for a decision. The instructor must be willing to help, to guide, and to suggest, but not select projects for the students. Letting the students select their own projects gives them a sense of responsibility and self-confidence that should aid materially in preparation for life. Giving help too soon or giving too much assistance would only cause them to lose confidence in themselves and to back into complete reliance upon the instructor. After students had done extensive reading in the fields of their interests they conferred with the instructor about availability of materials and procedures for doing their projects. It was very important that the students knew what they intended to do before they actually began work on the projects. The teacher was at this time very much aware of the individual differences of the students. Those with less than average ability were advised against doing difficult projects. Likewise, the abler students were encouraged to do something requiring much reflective thinking.

Students began work on their projects at the termination of twenty-four weeks of instruction in the basic fundamentals of chemistry. Occasionally, it was found desirable to vary the continuous laboratory work by having a day in the classroom. Such days were used in review of chemical equations, chemical calculations, common names of compounds, and progress reports. In the progress reports students told the entire class what project they were doing, the difficulties they encountered, the methods they used in overcoming these difficulties, and any other information that seemed pertinent.

The students made written records of their observations, difficulties which they encountered, and methods used in correcting these difficulties. Everyone was required to record results at the time they occurred in the laboratory. It was stressed that inaccuracy is one

of the greatest sins in the chemistry laboratory. The project reports were typed, double-spaced, on bond paper and included the following:

1. Statement of Problem
2. List of Materials—apparatus and chemicals
3. Procedure—explicitly described
4. Drawings and Labeling of Diagrams
5. Results—in table form
6. Discussion of Difficulties Encountered and Methods Used in Overcoming the Difficulties
7. Bibliography.

The instructor of English IV graded the reports for grammatical structure, and the present writer graded them for scientific content.

The pupils displayed their projects on cellotex and plywood sheets approximately 30"x36". It was found that cellotex looked much neater and actually was much more reasonable in cost. The cellotex and plywood sheets were framed and supported so that they would stand in an upright position. Each of the displays contained a title which was centered at the top of the exhibit. Samples of materials used in making the project were also displayed with the exhibits. Chemicals were placed in small bottles and fastened to the cellotex with #30 gauge copper wire. Names of the chemicals were typed on small labels and placed below the glass containers. Equipment used in making the projects was properly identified and displayed with the exhibits. The projects were displayed in the science rooms for the annual open house. Students were required to remain with their projects during the visitation hours. It was most rewarding to note the enthusiasm of the pupils as they discussed their end results with their parents and visitors.

One may find related evidence of such enthusiasm in statements made by Charles H. Stone:

> When Johnny sees one of these in the offering, just watch him. Here at last is the real thing! When he starts out on some small project with a very definite and tangible result as the end to be attained, he will go at that experiment like a puppy at a root. And if, when he has completed his project, you suggest that he assemble all related materials and make an exhibit of them, you will see the smile that won't come off.[8]

The use of projects greatly enriches a course in high school chemistry. There is no fixed syllabus and no units of work are prescribed. In the project method the fault more often lies with the teacher than with the method of pupils. It is much more difficult to teach by this method than to assign a prescribed amount of work from a textbook.

[8] Charles H. Stone, "A Strong Motivation in Chemistry," *School Science and Mathematics*, XXXVII (April, 1937), 460.

SETS AND NUMBER THEORY IN THE HIGH SCHOOL

DONALD RAYMOND BYRKIT

The Necessity for Teaching Modern Mathematics In the Secondary School

The present secondary school curriculum in mathematics is thought by many to be inadequate or out of date. Many quotations can be presented to illustrate the fact that something must be done about the subject matter in the high school mathematics curriculum. The following statements are representative: "Much of the curriculum . . . is out of date."[1] and "The course of study is out of date."[2] Much speculation has been given to the manner in which the mathematics curriculum should be changed. Many schools have chose to "accelerate" the gifted student with courses in college algebra, analytic geometry, and calculus. Others have taken the stand that modern mathematics or, more properly, modern methods in mathematics should be used to strengthen the mathematics curriculum. "Modern mathematics" is a term that is most often used to indicate a new approach to mathematics. Throughout this thesis the term "modern mathematics" will be used to indicate that approach. The approach is one of using the set theory to investigate the properties of mathematics. As Duren says, "The mathematical idea of set, together with logic, has become almost the symbol of modern ideas in mathematics."[3] The idea of introducing some modern mathematics into the high school curriculum is not original in this thesis.

May says:

> In the last few years there has been considerable discussion about the possibility of introducing into the secondary school curriculum topics such as logic, theory of sets, Boolean algebra, and the set theoretic approaches to relations, functions, and other topics of elementary mathematics. For lack of a better term such material has come to be called modern mathematics."[4]

Most high schools, however, have done nothing to modify the traditional curriculum, even though "the teaching of mathematics in our schools is the target of mounting criticism by mathematicians, scientists, and educators."[5] It is evident that something must be done.

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[1] Dael Wolfe, "Emphasis on Mathematics," *Science*, CXXIII (June 1, 1956), 965.

[2] "Spotlight on Science and Mathematics," *School and Society*, LXXXIV (August 4, 1956), 45.

[3] W. L. Duren, Jr., "The Maneuvers in Set Thinking," *The Mathematics Teacher*, LI (May, 1958), 332.

[4] Kenneth O. May, "Finding Out About 'Modern Mathematics'," *The Mathematics Teacher*, LI (February, 1958), 93.

[5] Frank B. Allen, "Mathematics Tomorrow," *Journal of the National Education Association*, XLVI (May, 1957), 48.

Many high schools, however, have neither the students nor the teachers to offer a full course in either college algebra or modern mathematics. A unit in modern mathematics, then, may be at least one step in the direction of a better mathematics curriculum. Some school systems are already working on the precept that the mathematics curriculum will change in the future and that some modern mathematics will undoubtedly be found in the new curriculum. *Time* magazine describes a class for teachers in Portland, Oregon, designed to prepare teachers

> for a curriculum in which the barriers between algebra, geometry and analysis are crumbling, solid geometry and trigonometry may disappear as separate fields, and algebra will deal with such topics as groups, rings, and fields. As one Portland student put it: "Even the concept of the line has changed. In geometry you may have learned that a line is the shortest distance between two points. In the future you will learn that a line is a set of points."[6]

Another Portland student remarked that " 'traditional algebra was taught as real numbers, and it was taught by rote. In the set theory, you can prove it logically.' "[7] In the traditional high schoool mathematics curriculum, "even the mathematics major has to wait a long time before he gets into modern mathematics."[8] The best students often study mathematics and science through most of their high school program,[9] so it is up to the curriculum to provide enough mathematics to at least give the better students an idea of what mathematics is all about. The University of Illinois program for high school students, in use in some high schools in Illinois and Wisconsin, includes a course called Theory of Sets.[10] *The Mathematics Teacher,* publication of the National Council of Teachers of Mathematics, often contains articles dealing with modern mathematics in order to inform mathematics teachers of the theory and use of modern mathematics. The emphasis on modern mathematics in literature and practice indicates that sets, theory of numbers, and many other topics heretofore confined to college mathematics courses, are now on the way to being incorporated to some degree in the high school mathematics curriculum.

Statement of Problem and Purpose of Teaching Modern Mathematics in the Secondary School

The problem undertaken by this study was to develop a unit in the foundations of modern mathematics teachable at the high school senior level such that the students might learn and retain, as well as

[6] "The New Mathematics," *Time,* LXXI (February 3, 1958), 48.

[7] *Ibid.*

[8] Wolfe, *loc. cit.*

[9] M. H. Ahrendt, "Mathematics and Science," *Journal of the National Education Association,* XLVI (February, 1957), 109.

[10] Modernizing High School Math.," *Scientific American,* CXCV (August, 1956), 50.

possible, the material presented. The purpose in doing so was to teach some of the fundamental concepts of modern mathematics to the students in such a way that they would gain familiarity and facility with some of the fundamental tools and language associated with modern methods in mathematics and that they would thereby gain some idea of the magnitude of mathematics. The unit was planned to open doors to these new ideas and concepts in the hope that the students would become interested in the realms thus revealed.

Since set theory is such a unifying concept and occupies such an important place in modern mathematics, it was necessary to spend much of the initial preparation on set theory. Unless the concept of sets is learned, much of the subsequent material is meaningless to the learners. It is important, therefore, to present sufficient material to insure understanding, at a level to allow easy comprehension. The material to be presented, then, must be elementary enough for the students to understand, yet enough material must be available to allow for the presentation of many examples to the class. It is the responsibility of the instructor to judge when the material has been mastered, just as in any unit. If the material available is insufficient, the instructor should supply some additional examples from his own background or from the bibliography. The main problem of the preliminary study, then, was to determine what material was to be presented, the order of presentation, time to be spent in the presentation of each section, and examples and problems to be included. In order to decide upon material for inclusion it was necessary to draw up a list of main topics which should possibly be included in the unit. Set theory is a definite must for any beginning unit in modern mathematics, since "the habit of thinking in terms of sets has become routine for most mathematicians, and has also become part of the everyday thinking of many other scientists too."[11] Number theory is also a basic tool of mathematicians. It is "the result of an evolution in thought over many centuries.[12] Some number theory must also be included. It was thought that some work on congruences and groups would be useful; however, during the presentation of the unit it was found to be necessary to spend additional time on mathematical proofs by induction, and consequently it was necessary to include instead a section on semi-groups, since the concept is easier to understand than group theory and time must be considered.

Description of the Teaching Unit

The teaching unit was taught to a class of senior students enrolled in a one-semester course in college algebra at the University High School, Illinois State Normal University, Normal, Illinois, during the month of May, 1958.

[11] E. J. McShane, "Operating with Sets," The National Council of Mathematics, *Insights into Modern Mathematics*, Twenty-third Yearboook (Washington, D.C.: The National Council of Teachers of Mathematics, 1957), 36.

[12] Ivan Niven, "The Concept of Number," The National Council of Teachers of Mathematics, *ibid.*, 7.

The unit began with a short historical introduction which led into the first main section on relations. Many relations were considered, with emphasis on equivalence and order relations. The conditions for an equivalence relation were given, and illustrations of equivalence and non-equivalence relations were discussed. The concept of relations, especially the order relation "is greater than," led logically into the basic concept of a set as a collection of objects, but no stress was laid upon the importance of ordering of sets. Many examples of sets were included in order to convey the concept that a set is a collection of "things" that have at least one characteristic in common. This is a relatively simple concept and is easy to convey to the students, since

> students make daily use of sets of books, pen and pencil sets, sets of table silver, etc. People of all ages and in all walks of life are constantly preoccupied with sets of elements—sets of blocks, sets of picture cards, sets of golf clubs, sets of teeth (possibly false), or simply the sets of fingers on their right hands.[13]

The further properties of sets were explored to the extent of subsets and algebra of sets as far as complements, intersection and join. It was necessary for the student to fully understand these concepts and operations, because they pervade mathematics. Each section must be learned before the next topic can be studied. For example the relation "is a subset of" is an order relation, and the concept of relation must be understood before the full meaning of subsets can be established in the mind of the learner.

After some of the properties of sets in general were explored, attention was directed to one particular set, the set of positive integers. Here the postulates for positive integers were introduced, and much time was spent on teaching the concept of prooof by mathematical induction. Some direct deductive proofs were included, but no indirect proofs. If enough time had been available, it would probably have been well to include some aspects of logic and indirect proof in the section on sets. It is imperative that enough time be spent on mathematical induction to allow for complete mastery. Mathematical induction is a difficult concept, and it is felt that set theory provides a means for viewing induction that may cause less confusion than the methods employed in most college algebra texts. It should be noted here that there are various methods for presenting the basic postulates for positive integers. After consideration it was decided to use the postulates of Peano for the sake of simplicity and ease of handling. Any formulation of a basis for the positive integers is incomplete without the principle of mathematical induction. Because many textbooks, even in advanced college courses, present a considerable amount of

[13] Bruce E. Meserve, "Implications for the Mathematics Curriculum." The National Council of Teachers of Mathematics, *ibid.* 405.

material on this topic, it is easily seen that it is beneficial to the mathematics student to become familiar with the principle involved as early in his schooling as possible. Accordingly, mathematical induction is considered to be one of the most important topics to be covered in the unit. A short section on divisibility is included in number theory to acquaint the student with the relation "divides" and to bring out the fact that this is an order relation.

The final section presented in the unit was intended to give the student a short glimpse of both the beginnings of group theory and the concept of transformations, using matrices. The matrices were not labelled as such, in order to avoid further confusing terminology, but it is expected that the concept alone (without name attached) will enable the student to beter comprehend matrices when he meets a more extended account. A semi-group is defined in this unit to be any set, together with a binary operation, which is closed under the operation and in which the associative law holds. The transformations used were those of a triangle into a side, and into a vertex. The simplest of these, the transformations of a triangle into a vertex, does not form a group under the operation of following one transformation with another, because there is no identity transformation in the set, but does form a semi-group, and is used to illustrate most of the properties dealt with in this section.

This, then, was the teaching unit which, together with review and examination, required approximately three weeks. At the conclusion of the unit it was hoped that the students would have acquired a new insight into the nature of mathematics and would be ready, willing, and, above, all, able to attempt comprehension of these and other topics in a more extensive form.

Most of the symbolism and methods of representation used in this unit were drawn from Garrett Birkhoff and Saunders MacLane, *A Survey of Modern Algebra* (New York: The Macmillan Company, 1953) and R. B. Kerschner and L. R. Wilcox, *The Anatomy of Mathematics* (New York: The Ronald Press Company, 1950).

Summary, Conclusions, and Recommendations

Since the unit consisted of material new to the students, its nature was introduced to the class before actual presentation began, and the class was instructed to feel free to voice any comments they might have at any time. In addition, student comments were also requested at the conclusion of each class period.

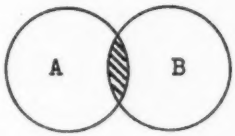
These student comments were responsible for some changes in the unit during the course of presentation, especially in provision of additional time for the mastery of mathematical induction, since the concept was more difficult for the students to understand than had been anticipated, and the consequent replacement of the originally planned section on congruences and groups by a shorter section on transformations and semi-groups.

Venn diagrams were used to aid the students in understanding set operations and relationships. A rather simple and helpful device was evolved following a suggestion by a student. The device, which was thereafter used in teaching the unit in conjunction with Venn diagrams until the Venn diagrams were completely understood, consisted of using line diagrams to supplement the ordinary Venn diagrams. It was found to promote understanding if, in addition to sketching on the blackboard the ordinary Venn diagram of two sets of positive integers, such as

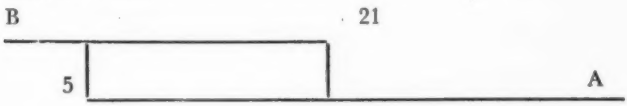
$A: \quad [a \in A;\ a > 5]$

$B: \quad [b \in B;\ b < 21]$

as



where the shaded area is their intersection, the two sets were also represented as lines (which may be thought of as side views of the Venn diagram) thus:



where the section between the vertical lines indicates their intersection.

From the questions asked by students, it was found important to explain why the join of two sets gives a result that seemingly contradicts the Euclidean adage that "the whole is equal to the sum of its parts." In set theory, only mutually exclusive sets are found to agree with this "axiom." Any two sets which have an intersection will form a set which will have fewer elements than the total of the number of elements in the original sets. To phrase it differently, if set A is the join of sets P and Q, the cardinal number of set A will be numerically smaller than the sum of the cardinal numbers of sets P and Q unless P and Q are mutually exclusive sets. In the main, the class enjoyed the section on sets and found it easy to understand.

The section on number theory dealt with the postulates for positive integers, inductive and direct inductive proofs, and divisibility. A total of five class periods was spent on number theory. The main difficulty was encountered in teaching mathematical induction. It was necessary to spend much time in the explanation and illustration of mathematical induction, and it was found helpful to spend some time on board work. Induction is a difficult concept, and questions concerning the validity of the assumption of a proposition for "k" ("How can you assume what you're trying to prove?") were best answered by asserting that there exists at all times a set, which may, however,

be null, for which the proposition is always true. Once it has been proven that unity is a member of the set, it cannot be a null set; hence the number "k" is one such element of the set for which the proposition is always true. All that remains, then, is to prove that the set in question is the set of all positive integers. It was also found necessary to provide the students illustrations more concrete than those which bear directly on number theory. The greatest success was achieved by demonstrating the axiom of induction with the proof that the sum of the first "n" integers is equal to "$\frac{1}{2}n(n+1)$" and the proof that the sum of the first "n" odd integers is equal to "n^2". It was found that the students understood the concept of induction best by doing a few examples themselves at the blackboard. On the test given at the conclusion of the unit, only one student was unable to adequately present an inductive proof, and he showed some understanding of the principle of induction. He gave a few examples, then drew an incomplete induction. Still, he set the problem up properly, merely failing to follow it through to the correct conclusion.

By and large, the section on number theory, especially that on mathematical induction, was the most difficult in presentation and the most difficult for the students to understand. However, the importance of number theory is beyond question, for the theory lies at the very base of mathematics.

The final two periods were spent on transformations and semi-groups. The purpose of these topics was to give the students just a taste of the beginnings of group theory in the hope that they would become interested in further implications and applications. During the first of the two periods, the transformations of the triangle, set up in matrix form, into a triangle, a side, and a vertex were explained to the class and the operation "o" of following one transformation with another was defined. The concept of semi-group was defined, multiplication tables set up, and the sets were examined to see if they formed semi-groups under the operation "o". Any set, together with a binary operation under which closure and the associative law hold, is defined as a semi-group. The students were also pointed in the direction of group theory as groups, rings, and integral domains were also mentioned. Many of the students were eager and willing to go on to the study of groups and asked for references where they might learn more about group theory. The tables of multiplication under the operation "o" proved to be of great interest. The results of the unit examination, however, showed that some of the students were not clear about the definition of a semi-group, especially concerning the associative law. The multiplication table of the transformations of a triangle into a vertex under the operation "o" were understood by most of the students, but evidently the definition of a semi-group did not receive enough emphasis in class.

At the conclusion of the unit the students expressed great delight in studying something new and different. More than one student wanted to do more work in the realm of modern mathematics. The

best-liked sections were those on sets, particularly "that cap and cup business" and complements, and on transformations.

The unit examination was administered after two days of directed and non-directed review. The first period of review was spent reviewing concepts deemed important by the instructor; the second review period was spent answering questions of the students. The total results of the examination indicated a high degree of comprehension and seemed to correlate closely with the semester grades received by the students.

The purpose of the unit in modern mathematics presented in this thesis was to give the students some familiarity and facility with a few of the basic tools and language associated with modern methods in mathematics. To provide a basic grounding in modern mathematics, sets and number theory were emphasized, with an additional amount of material on relations and semi-groups presented. Basic to understanding the fundamental concepts behind set theory are the notions of what, exactly, constitutes a set and what is to be done with the sets after they are obtained. Accordingly, the students were taught, and were tested on, the concepts of set, complement of a set, intersection and join of two or more sets, and subsets. They were given some notation and operations in order to acquaint them with sets, and acquired a great deal of facility with the operations governing sets and set behavior. That they understood the concept of sets and set operations was evidenced by the fairly high class average on the unit examination dealing with sets.

Relations, an important mathematical concept, were taught to the class, with emphasis on equivalence and order relations. Understanding of relations was considered to be of vital importance to any understanding of the basic concepts of any mathematics. The class average on that question was high, a fact which indicated that relations were well understood.

Number theory, the basis of mathematics as it is known most generally today, received emphasis on the basic postulates for positive integers, mathematical induction, and direct deductive proofs. The unit examination showed that the students were well able to carry out proofs and understood the basic concepts of number theory.

The least emphasized, and thus least well understood, section of the unit was the final section concerning transformations and semi-groups. The students were expected to know operations with transformations and the difference between a set and a semi-group. On unit examination questions concerning transformations and semi-groups indicated that the section could bear more emphasis. Thus the unit evidently succeeded in its purpose of familiarizing students with basic concepts and tools of modern mathematics.

Although the unit was limited by a time factor, the amount accomplished within three weeks indicates that some modern mathematics is certainly within the understanding of some high school students. The comments of the students indicate that they are willing

and eager to learn the new approach to mathematics that is known as "modern" mathematics. One of the students, who intends to become a teacher, remarked that she was glad to learn that there was more to mathematics than mere manipulation. Thus it is very probable that some modern mathematics, notably sets and number theory, at least to the extent covered in this unit, could be incorporated into the high school program, probably in connection with the course in college algebra offered in a great many high schools. One of the contributions of this unit to the understanding of the students is the demonstration of generality and the use of broad concepts. It is this generality that makes modern mathematics so valuable. It might even be profitable to go further, as some high schools have, and institute a one-semester, or, if possible, a full-year course in modern mathematics in the high school curriculum, probably in the fourth year. Such a course might be taken as the fourth year or eighth semester of high school mathematics or concurrently with the fourth year, and offer such topics as theory of polynomials, applications of set theory to logic and electrical circuits, operations with matrices, theory of rings, groups, integral domains, and fields, as well as extensions of the subject matter covered in the unit contained therein such as the theory of inequalities, further algebra of sets, extension of the theory of numbers to include negative, rational, and real numbers, and transformations. Such a possibility might well be a fruitful subject for another research. In addition, it would probably be valuable to conduct studies similar to the one undertaken in this thesis in order to investigate the possibility of presenting material similar to that presented in this thesis at less advanced levels, or presenting a more extended unit at the same level.

JOHN DEWEY BRIEFLY REVISITED

SCOTT BLANKENSHIP

This is the centennial year of the birth of John Dewey. The world knows him as one of the giant intellectual figures of this century. He is to be placed alongside Plato and Aquinas, Hegel and Kant, Spinoza and Hume, and all the other illustrious philosophers of history.

His intellect was catholic, penetrating and seminal. No other contemporary thinker—Russell, Whitehead, or Santayana—has assayed more of a breadth and depth of experience that has Dewey. His thinking has run the whole gamut of knowledge—philosophical, psychological, logical, ethical, religious, historical, esthetic. All dimensions of mind have come under the scalpel and ministration of his analysis.

His legacy to us is the accrued wisdom of his three score and ten years of philosophical inquiry, which itself was the steady exemplification of the emphasis that he gave to the ethic of the obligation to be intelligent.

Yet, ironically enough, a kind of paradox that demeans Dewey attends the pedagogy which has made him most known to his own countrymen. To many people, Dewey is the culpable progenitor of, is synonymous with, this "new," so-called progressive education about which there is the present great controversy. Because of him, some voices have already prophesied our doomsday. There is the dark and dire hint that our education may never recover from the intellectual enervation caused by the "Deweyian" idea of a child-centered school that gives too much latitude to capricious students who suffer the intellectual privation of the practical activities that equate with learning by doing. There is the feeling among some of his critics that if the Russians gain the skies then surely Dewey will inherit limbo. But many of us are all too familiar with the useless stereotyped criticism of the uncritical sloganized progressive pedagogy and know that Dewey himself was compelled to correct the distortion of his ideas that was done even by his own adherents. This setting aright those who misconstrued him he did with his *Experience and Education* of 1938, a significant study that few of his critics give little evidence of having read.

The anomaly that attaches to Dewey is the point of Dr. James Conant's observation that even if Dewey had never lived we would have had to invent him. Just what is meant? Precisely this, that apart from the intrinsic intellectual merits of Dewey's theory of education, his ideas have been used to provide both a rationale for and a rationalization of a *fait accompli*. To explain this, let us go back to 1918, the year that the Seven Cardinal Principles were promulgated for secondary education. The Cardinal Principles have been explained as the sanction that the teaching profession gave to the aim of the public to create a school that would more nearly mold students to the

social matrix than develop intellectual abilities. At that time this was already to a large extent the emerging form of our secondary education. It has since crystallized. That just one principle, *viz.,* command of fundamental processes, of seven created for secondary school, would have strictly intellectual purpose certainly seems to confirm the point. Herein, then, lies the paradox. Dewey has had precious little to do with certain aspects of the public school that so many critics deplore.

Democracy and Education is Dewey's definitive philosophy of education. This was just two years before the Cardinal Principles and one before the Smith-Hughes Act, which together justify and provide for a vocational and technical curriculum for other purposes than, for example, the aims of education of those chapters from *Democracy and Education* that deal philosophically and reconstructively with the intellectual and moral dichotomies that we have made of play and work, of labor and leisure, of the intellectual and the practical. The acute need for the skilled labor to maintain a growing technology would partly explain the vocational program of the high school. And the often-criticized "practical" character of the curriculum is to an extent a matter of teachers trying to find suitable learning experiences for the congenitally hand-minded and non-bookish student. Unavoidably, the effect has been to introduce some materials of a low academic quality into the curriculum. But this is specific. Aside from the particular, we would know that when education becomes as universal and grass-roots as our own, society and school are then a mutuality. Such a school, of necessity, will mirror the essential and pervasive elements of its culture. There is much with us that is practical thing-centered and theory-discounting. The wonder is the naivete of those scholastics who imagine that the common education of such society could be so grievously disjunctive as to be exclusively academic after the classical pattern. A basic law of cultural determinism is neglected.

The point then is that perhaps more than we realize we have appropriated Dewey's theory to give intellectual respectability to practical necessity. As Conant put it, we would have had to invent him. But this is not to argue that Dewey has had little, if any, directive effect upon education. Dewey has definitely had such an impact, several-sided as a matter of fact. A lot that is intelligent and good in education is the fruit of his thinking. It is the distorted sides that have plagued Dewey. Besides the rationalizing uses of Dewey, the other untoward side, also with consequences very uncomplimentary to him, is those unmitigatedly child-centered Rousseauan schools, the creators of which claim that their innovations implement what is basic to Dewey. The compliment is left-handed and the sin is compounded. Dewey would bless neither house. The question thus raised is what did Dewey *really* say about education. No particular conception will convey his essential meaning. His thought is too wide and deep to lend itself to shibboleths. Only a sustained critical reading gives access to the insightful ideas of teaching and learning that his pedagogy offers.

Should we who teach and who would so briefly commemorate Dewey's work ever wonder what one single precept of all of his writing he would have us remember, I would guess that it would be the last sentences from *Experience and Education*. More than anything else, I believe he would remind us again that:

> . . . the fundamental issue is not of new versus old education nor of progressive against traditional education but a question of what anything whatever must be to be worthy of the name *education*.
>
> . . . The basic question concerns the nature of education with no qualifying adjectives prefixed. What we want and need is education pure and simple, and we shall make surer and faster progress when we devote ourselves to finding out just what education is and what conditions have to be satisfied in order that education may be a reality and not a name or a slogan.

FORGOTTEN FOOTNOTE

In a recent study of American high schools, Dr. James B. Conant, former president of Harvard University, contended that a high school having a graduating class of less than one hundred cannot provide an adequate program for educating all youth in the community. However, from Cape Canaveral comes the report that the majority of men doing the most important scientific work and holding the most responsible positions graduated from high school in classes of less than forty students. Obviously, to prepare scientists is only one function of the high school, and it may be that these smaller schools presented offerings that failed to meet the needs of students desiring to enter other vocations. Nevertheless, when these schools prepare a majority of the workers in the field of science, an area in which their program of studies is usually rather limited, this is a very significant finding. While the findings from an investigation that concerns only one establishment must not be regarded as conclusive, they do tend to indicate that mere enrollment as such may not be a good index of a school's service to the national welfare. Educators should be wary of standards that are arbitrarily fixed on the basis of only one aspect of the school, such as enrollment. Such points of demarcation invariably neglect the effectiveness of the teaching, the zeal of the students, and the inspiration provided by individual teachers. When compared with these more weighty factors the size of the schools is often of little significance.

CERTIFICATION OF PSYCHOLOGISTS

For many years the Illinois Psychological Association has worked for statutory certification of psychologists to protect the public against the quack and the poorly qualified individual. To date these efforts have not been successful; therefore, the members of the Illinois Psychological Association voted in 1958 to institute non-statutory certifications and authorized the establishment of a Board of Examiners. Dr. Stanley S. Marzolf, Secretary-Treasurer of the Board, reports that as of October 20, 1959, one hundred and forty certificates have been issued. He also reports that a directory of certificate holders will be issued for general distribution early in 1960.

Under this certification program the psychological profession is so interpreted as to include "those who, by virtue of their psychological knowledge and skills, teach, engage in research, serve as administrators, or serve as consultants to clients." A qualified applicant is certified as a psychologist without reference to his specialty. Anyone wishing further information should address inquiries to the Secretary-Treasurer, 403 Corn Belt Bank Building, Bloomington, Illinois.

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SPECTROPHOTOMETRIC STANDARDIZATIONS FOR QUANTITATIVE ANALYSIS

RONALD ARCHER

Analytical determinations in industrial laboratories are dependent upon processes having speed and efficiency as well as accuracy. Spectrophotometry and similar colorimetric means are rapid, require a minimum quantity of test solution, and are ordinarily accurate to the limits desired by analytical laboratories. The author has observed the use of spectrophotometric processes in industrial, medical, and academic laboratories across the nation.

The need for emphasis on spectrophotometry in the training of chemists has often been pointed out by leading industrial and academic chemists. Many colleges and universities have added courses in instrumental methods of analysis which include emission spectroscopy and electrical processes as well as absorption spectroscopy. These courses usually have a prerequisite of one or more semesters of classical quantitative analysis(*i.e.*, volumetric and gravimetric determinations).

Still a problem remains—there is a definite need for introducing spectrophotometry to the student who will only take one semester of quantitative analysis. This is especially true in junior colleges, teacher-training institutions, and the premedical curricula of other colleges and universities. In these instances the student very seldom has the opportunity to enroll in more than one quantitative analysis course if he is to receive a well-rounded education. Therefore, it should be the duty of the chemistry staff to see that the student has an opportunity to receive at least an introduction to the important analytical tool of spectrophotometry in his first quantitative analysis course. This paper includes a few spectrophotometric determinations of solutions already used in the volumetric portion of most quantitative analysis laboratory courses.

Nomenclature

The integration of spectrophotometry with volumetric analysis requires not only the principles ordinarily associated with the classical course, but also the terminology, theory, and practical application of colorimetry.

Colorimetry, as the name implies, it the measurement of color or some property related to color. Thus it includes the determination of different hues as well as the intensity of a single color. In this broad sense of the word, many phases of chemical analysis may be included. Visual comparison of standard solutions with unknowns, once the extent of colorimetry, is now only a small part of the existing field. Two examples of fairly recent additions to the domain of quantitative analysis are filter photometry and spectrophotometry.

Color may be defined as the selective absorption of radiant energy (such as ultraviolet, light, and infrared waves).

Absorption spectroscopy is the field of colorimetry concerned with the absorption of radiant energy at various wave lengths.

Spectrophotometry is quantitative absorption spectroscopy. This area of colorimetry is concerned with the relative absorption of solutions by measurement at various wave lengths and with the determination of elements, ion, and compounds (either qualitative or quantitative) as the result of this absorption. Instruments capable of measuring the absorption at any wave length within the range of the instrument are known as spectrophotometers.

Filter photometry is very closely related to spectrophotometry. It differs only in that the measurements are made on instruments capable of measuring certain definite wave lengths according to the filters available. Thus it is sometimes called abridged spectrophotometry.

Millimicrons (mμ) are the wave length units most commonly used in visual spectrophotometric work and are equivalent to ten angstroms.

Transmittancy (T_s) refers to the ratio of the intensity of light (or similar radiant energy) passing through the cuvette filled with the solution being measured to the intensity of light passing through the solvent or the solution minus the desired constituent in the same or an equivalent cuvette.

Absorbancy (A_s) is the negative logarithm of transmittancy. Symbollically $A_s = -\log T_s$. This term $-\log T_s$, is also designated by some authors and on some instruments as **optical density** (D) or **extinction** (E).

Theory

Visual spectrophotometry is based on the separation of light into its spectrum as can be shown with a glass prism. This breakdown of white light is not in definite lines, but is ordinarily changing hue from the deepest violets (wave lengths of 380-400 mμ) to the deepest reds (wave lengths of 700-760 mμ).

Visible color, the selective absorption of light, is definitely related to the spectrum. A solution looks red, for example, if it transmits the red wave lengths of light to a greater extent than the other wave lengths. In the region from 400-600 mμ little light is transmitted but in the region from 600-700 mμ a considerable amount is transmitted. Since the violets, blues, greens, and yellows (having wave lengths of 400-600 mμ) are not transmitted nearly as much as the reds (having wave lengths above 600 mμ), the solution looks red. This selective transmission is accomplished by the absorption of light of other wave lengths.

Beer's Law. An equal fraction of light intensity is absorbed by

an equal number of like molecules. The use of absorption for the quantitative analysis of chemical solutions is largely dependent upon this simple principle. If one-half of a certain light is absorbed by two millimeters of a colored solution, one-half of the remaining light will be absorbed by the next two millimeters, and so on through the solution. Likewise in another colored solution of the same coloring material but twice as concentrated, one-half of the same light is absorbed by one millimeter of the solution, one-half of the remaining light is absorbed by the next millimeter, etc. This exponential function of absorption can be stated by the following equation

$$\log I_o/I = k\,c\,d$$

where

I_o = intensity of light striking the solution
I = intensity of light leaving the solution.
log = logarithm to the base 10.
k = a constant for a certain molecule and a certain wave length of light
d = distance of light path through the solution.

This equation is a logarithmic form of Beer's law. Since I/I_o is the same as the transmittancy (T_s) the law may be expressed as

$$-\log T_s = k\,c\,d$$

and designating $-\log T_s$ as the absorbancy (A_s), the logarithmic form becomes

$$A_s = k\,c\,d$$

This expression is useful in quantitative analysis because a plot of the concentration of solutions against absorbancy in the same or identical cells will give a straight line. This holds as long as there is no shifting in molecular structure over the range on concentrations plotted.

Instrumental Procedure

Reproducible measurements of absorption spectra require certain constant factors. The best procedure for absorption measurements with commercial instruments is to carefully follow the manufacturer's instructions. Periodic wavelength calibration is important for both qualitative and quantitative determinations. Flat faced cuvettes are preferable, as cylindrical solution cells have a lens action and no definite path lengths. Cuvettes should be matched (*i.e.*, tested for equality of transparency) prior to use in quantitative experiments. For maximum accuracy, the absorbancy readings should be kept between 0.095 and 1.00, that is, between 80% and 10% transmittancy.

Application

High school teachers with limited training and experience may find this study an aid in familiarizing themselves with the newer methods use in quantitative analysis. Teachers who have exceptional students as members of a high school chemistry class will be able to use the material on instrumental analysis as an enrichment and chal-

lenging addition to the regular work. For those teachers who are working with students taking advanced courses in high school chemistry it presents teaching material that is in keeping with current methods of instrumental analysis.

The instructor may integrate these spectrophotometric analyses with his chemistry course in whatever way he desires. If he is not very well acquainted with the spectrophotometer at his disposal, he should study the directions that came with it carefully and try some determinations to obtain a working knowledge of the instrument. He may then begin teaching the students the nature and use of spectrophotometry. The method used to approach the subject will vary with each teacher. Spectrophotometric analysis may have a definite place in the course or it may be subtly introduced.

If the study of spectrophotometry is to have an integral part in the course, it is suggested that the students having good results on their determinations with volumetrically standardized potassium permanganate save these solutions for the plotting of spectrophotometric curves. Naturally, the solutions must be stored in brown bottles to hinder decomposition of the permanganate ion. Potassium permanganate is suggested here because, at present, most quantitative analysis courses use standardized potassium permanganate as an oxidizing agent; and unlike potassium dichromate and iodine, which also may be used, potassium permanganate has an absorbancy maximum in the range of the relatively low priced Bausch and Lomb "Spectronic 20" and the Coleman "Junior." Slight variations in the wave length causes less deviation from ideal behavior than if the side of the absorption curve is measured. Therefore, measurement on the side of the absorption curve is considered poor practice unless absolutely necessary.

As a second possibility, the teacher may decide to wait until a student mentions inconsistent results on his standardizations of one of the reagents. This will undoubtedly occur and give the instructor a logical place to introduce spectrophotometry. Iodine and potassium dichromate may be used with this approach, but accuracy is lower than with potassium permanganate.

Regardless of the method used to introduce the subject, the principles, applications, and limitations of the instrument should be included in the beginning quantitative analysis course along with an explanation of spectrophotometry in industrial analysis. The spectral curves of those reagents can be used to determine the wave length at which absorbancies of unknowns should be measured. The concentration-absorbancy curves should be determined on the instrument to be used and should be rechecked rather frequently as a slight change in the wave length will cause discrepancies in the absorbancy readings (especially in the case of iodine and potassium dichromate solutions).

The normality of sodium thiosulfate solutions can be determined by the decoloring of iodine solutions. A definite amount of sodium thiosulfate is added to an excess of standardized iodine solution. The extent of the decoloration of the iodine solution can be measured

spectrophotometrically and the normality of the sodium thiosulfate solution calculated. This determination is more complex and undoubtedly should be reserved for analytical chemistry above the sophomore level or for exceptionally good students.

Acids and bases may be standardized by the addition of a definite quantity of a suitable acid-base indicator and the measurement of absorbancy at two wave lengths, preferably those of maximum and minimum absorption for the acid-base indicator. The relative absorption will vary with the concentration of the acid or base. A plot of absorbancy differences with respect to concentration of the acidic or basic substance shows a definite scatter rather than a smooth curve unless micropipettes are used to insure absolute indicator volume. If, however, the differences in the logarithms of the absorbancies are plotted against the concentration, the scatter disappears even with approximate indicator volumes (*e.g.*, two drops of indicator per five milliliters of solution). The full derivation of this relationship and detailed instructions for its use may be found in the original thesis.

The standardizations of redox reagents, acids, and bases, as suggested in this paper can be performed on low-priced spectrophotometers. However, the precision is not as good with the chemical methods, so some instructors may prefer to use spectrophotometry only as a checking or approximation tool. In any case, it seems desirable to consider the inclusion of this modern analytical tool in basic quantitative analysis courses.

A SANITARY SURVEY OF MILLER PARK LAKE, BLOOMINGTON, ILLINOIS

E. I. Rhymer

(This paper is a condensation of a thesis study by Charles J. Morrison made in 1950 under the supervision of Dr. Ernest M. R. Lamkey.)

A dispute between the City of Bloomington and the State Department of Public Health about the condition of the water at Miller Park Lake resulted in the City of Bloomington's operating the beaches at Miller Park Lake even though the State Department of Public Health had virtually condemned them. This study (1950) was made over a period of one year in order to determine whether Miller Park Lake was safe for swimming. Bacteriological examination of the water, chemical examination of the water, a survey of the terrain adjacent to the lake in order to determine the source of drainage into the lake, a check of the sanitary aspects of the bathhouses and beaches, and a check of the policies governing the supervision of these places were made.

Permission to conduct this survey was granted by Mark B. Hayes and C. C. Williams, respectively Mayor and Superintendent of the Water Works, City of Bloomington, at that time.

Miller Park Lake is an artificial lake formed in 1896 by building a dam where the arched stone bridge between the two parts of the lake now exists. Thus the eastern half of the lake, as it exists today, represents the first lake built in the park. One year later a second earth dam was erected to the west of the first dam and the old dam opened permanently so that water could flow from the first part to the second, and the two parts formed one lake. Each part is approximately one-fifth of a mile long with the widest part of two hundred yards located in the southwest end and the narrowest portion of fifty yards located at the far east end. At its deepest points the lake has a depth of about twenty-five feet. The shore line is regular and the vegetation consists of cultivated grass and trees.

The east part lies in a valley with rather steep slopes on both the northwest and southeast sides. The northwest slope drains a rather large park area. Almost all of this ground drains indirectly into the lake by means of drain outlets located in gutters on both sides of the lake shore drive which borders this end of the lake. From the east some surface runoff of two city streets enters the lake by tile at the bridge on Summitt Street.

The southeast slope of the east part of the lake drains the south shoreline drive, which it part way up the slope; a rock garden area; and the tennis court. The rock garden area has two pools, the water from which trickles down the slope into a drain outlet connected to a tile which runs under the drive and down into the lake. In addition another grassy ravine to the south of the south lake shore drive is drained by tile into the lake.

The west portion of the lake has far less surface drainage than the east part of the lake. The north shore of this portion of the lake receives surface water from the grassy waterfront between the park drive and the edge of the lake and from the park drive itself. The drive between the animal house and pavilion slopes toward the lake, and the drive between the pavilion and the lake slopes in an easterly direction, both drives carrying water to outlets in the gutters of the drive running east and west along the lake shore. Water from this roadway drains into the lake by tiling at two places, one about 150 feet west of the bridge and the other near the center of the children's beach. The parking area just north of the children's beach is drained by an outlet which carries the water over the spillway, so none of this drainage enters the lake.

The south side of the west part of the lake has very little drainage into the lake, for the slope is such as to direct the drainage away from the lake, and there is little or no drainage into the lake at the west end where the second dam was constructed.

The swimming areas have brick bottoms covered with sand. There is a two-inch standpipe centrally located along the fence which divides the children's and adults' swimming areas. This standpipe delivers chlorinated city water to the lake daily from one to nine p.m. during the swimming season. Further, there is a very large spring located at the east end of the east part of the lake. A large tilepipe at the west side of the west part of the lake is used to drain the lake whenever it becomes necessary. The spillway for the entire lake is located at the northwest corner of the west portion of the lake. The water that goes over the spillway empties into a city sewer.

It was concluded from this consideration of the topography of the terrain surrounding the lake that although there is surface drainage into the lake, it was of a harmless nature from the park drives, park slopes, and about two city blocks of concrete pavements.

Water samples were collected from the lake at weekly intervals during the warm summer months and biweekly intervals during the cold winter months. The samples were taken from the swimming areas and other points of significance; that is, those where there was surface drainage into the lake and where the lake has its overflow. These were checked for pollution by use of bacteriological and chemical tests. The procedures for bacteriological, chemical, physical, and microscopic tests for the examination of water are specified in *Standard Methods for the Examination of Water and Sewage,* published by the American Public Health Association.

The bacterial examination of water consists of determining the number of viable bacteria and the presence of culiform bacteria. The total number of bacteria is determined by counting the number of colonies which develop in nutrient agar pour plates innoculated with appropriate dilutions of water samples. The total number of bacteria in water is roughly proportional to the degree of pollution, but the numbers present do not give information as to the kind of pollution.

The public health aspect of pollution in swimming areas centers around determining the presence of the organism of human fecal pollution because the gravest source of the massive epidemics up to the early 1900's of bacillary dysentery, typhoid fever, and paratyphoid fever, diseases of the intestinal tract of man, were primarily from water borne human fecal contamination. Therefore, if one determines the presence in a water sample of an organism which is common to the intestinal tract of all humans, that sample is suspect for any epidemeological intestinal organism of man, and thereby a health hazard. The organism from which human fecal pollution is determined is *Escherichia coli,* an organism which is a constant inhabitant of the human intestinal tract and does not cause an intestinal disease. The presence of *Escherichia coli* was determined by the procedures of *The Standard Methods for the Examination of Water and Sewage* as modified by Dr. E. M. R. Lamkey.

Bacterial counts indicating the total number of all kinds of bacteria made during the year ranged from 25,000 colonies/ml. of the lake water to 130 colonies/ml. of the lake water. Over three-fourths of these counts were less than 5000 colonies/ml. of lake water. The occasional high counts appeared at odd times and suggest that these high counts were due to chance roiling of the water by waders or animals, or to rains which washed soil borne bacteria in large numbers into the water just prior to the collection of the sample. These counts were lower than that expected from an open body of water subject to surface drainage. Whether these low counts were due to the small area of surface drainage, to the nature of the area drained, to the residual chlorine content (ranging from less than 0.05 p.p.m to a minimum of 0.075 p.p.m. residual chlorine in all samples) or to some other factor is a matter for conjecture. This low bacteria count* was one piece of evidence that the lake was suitable for swimming purposes; for in general, the greater the number of organisms found in a body of water the larger the amount of organic matter present and the less suitable is the body of water for human usage. During the swimming season, June, July, and August, eight out of thirty-three samples of Miller Park Lake water were found to have *Escherichia coli* present. Of these eight instances, three showed a considerable number of *Escherichia coli* present and therefore moderate to heavy pollution with human fecal waste. However, this evidence of pollution was sporadic and bathers were in the area where the contaminated samples were taken. These results could be attributed to bather pollution. The other five instances showed the lowest amount of pollution which could be recorded by the method used.

During the non-swimming season, five of the seventy-five samples taken showed the presence of a large number of *Escherichia coli* and the possibility of a large amount of fecal waste. However, the number of samples giving this evidence was so small and the occurrence was

* Editor's Note: (Unpasteurized Grade A milk can contain 50,000 colonies of bacteria/ml.)

at such irregular intervals that it was probable that chance animal pollution had occurred, for *Escherichia coli* is present in the intestines of most casual animals to be found in the park. Thirteen of the samples showed the lowest amount of pollution which could be recorded by the method used.

While there is no uniformity in the bacterial standards for natural outdoor bathing facilities, the interpretation of the bacterial tests conducted on Miller Park Lake indicated that the water of the lake ranks at the top in suitability for swimming.

Chemical tests on the water included the relative stability test, dissolved oxygen content, chlorine content, and the determination of pH.

The relative stability of the water, that is the per cent ratio of oxygen available as dissolved oxygen, nitrate and nitrate oxygen to total oxygen required to satisfy the biochemical oxygen demand of the water had a relative stability of 99% which is the highest percentage which could be recorded. This can be interpreted to mean that there was a striking absence of sewage or other organic matter in the water. The tests run throughout the year for the dissolved oxygen content of the lake water revealed a minimum dissolved oxygen content of nine parts-per-million, which is a condition of super-saturation. This super-saturation was explained by the presence of oxygen producing algae in the water. Nine parts-per-million is a very high dissolved oxygen content, since the presence of large numbers of bacteria or decaying organic matter would require large amounts of oxygen and thereby lower the amount of dissolved oxygen in the water. So again it is concluded that there is minimal organic and microorganic pollution.

In all tests for residual chlorine the water samples always showed a slight excess of chlorine over that required to satisfy the demand of organic matter in the water, especially during the more critical swimming season when it was 0.075 p.p.m. It is fair to suggest that this excess chlorine exerted a definite germicidal effect and may be one of the factors causing the low bacterial counts.

The majority of the tests for pH (degree of acidity) of the lake water indicated pH 8.4 and above; the lowest for the twelve month period was pH 8.0. This rather high degree of alkalinity is not a favorable environment for most bacteria, including *Escherichia coli*.

In summary it can be said that the relatively small amount of surface drainage, the low bacterial population, the low organic content of the water as indicated by high relative stability tests, the high dissolved oxygen content, the slight excess of residual chlorine and the rather high degree of alkalinity all combine to classify the water of Miller Park Lake a natural bathing water of the highest standard.

A survey of the sanitary aspects of the bath houses and beaches showed that the maintenance was satisfactory with only a few improvements needed. The supervision of the bath houses, however, was not adequate, but the beaches were in good condition, and supervision of the bathing was adequate.

EFFECT OF ANTIBIOTIC COMBINATIONS ON CERATOSTOMELLA ULMI, THE FUNGUS PRODUCING DUTCH ELM DISEASE

Thesis by Ronald John Menozzi—Summary by R. J. Menozzi and E. I. Rhymer, August, 1956

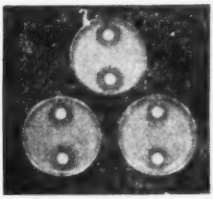
With the widespread development and use of antibiotics in the treatment of human and animal infection, investigators have been endeavoring to isolate antibiotic substances that could be used to control plant pathogens. Of the vast number of antibiotics that have been discovered and tested against plant pathogens, only a relatively small number have proved of any value in the control of plant pathogenic fungi. The use of combinations of antibiotics has been successful in the field of medicine as well as in the control of some bacterial plant pathogens. To this end, combinations of antibiotics may eventually bring a solution to the control of plant pathogenic fungi. The present investigation was undertaken to determine the action of antibiotic combinations on the fungus *Ceratostomella ulmi,* the organism which causes the Dutch elm disease.

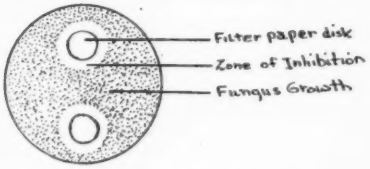
The Dutch elm disease is the common name given to the wilt of elm trees caused by the fungus *Ceratostomella ulmi.* The disease was first noted in Northern France, in Belgium and Holland in 1918, and was introduced into the United States from Europe on elm burl logs for veneer manufacture. It was first observed in Ohio in 1930, and has since spread to the Atlantic Coast in the East and to Colorado in the West. The spores of the fungus are spread from diseased trees or elm wood to healthy trees by the elm bark beetle, which carries the spores on its body. Here in the United States the disease is spread by the smaller European elm bark beetle and by the native American elm bark beetle.

The appearance of diseased trees varies considerably according to the time of year. In June or July, elms may show wilting or shriveling of the leaves on one or more branches. The wilted leaves may dry out rapidly, turn dull green, and fall from the twigs, or may turn brown and remain for some weeks on the tree. During midsummer or later the symptoms are usually confined to a definite part of the tree or even to a few twigs, and the leaves turn yellow, then brown, and fall. Internally the water-conducting tubes in the wood are discolored brown being clogged with tyloses (protrusion of enlarged parenchyma cells into the conducting cells) and a brown gum like substance. Even with these symptoms the disease cannot be definitely determined without laboratory tests of infected wood tissues because of the similarity of these symptoms to those of other diseases of elms.

The horizontal diffusion method was used for measuring the effect of antibiotics and antibiotic combinations on *Ceratostomella ulmi* grown on modified dextrose agar. In this method a known dosage of antibiotic or antibiotic combination in a fixed volume of water is dropped onto a uniformly sized disk of filter paper which has been

placed on a petri plate which has been seeded with a known number of spores suspended in the growing medium. From this wetted disk the antibiotic diffuses in a circular area, and if it is effective against the fungus seeded upon the petri plate there will be no growth in the area into which the antibiotic solution has diffused. Each plate so prepared is incubated under conditions suitable to the organism and at fixed intervals of time the plates are observed for growth. The areas in which there has been no growth are transparent, and where growth has taken place there is an opacity dependent on the vigor of the culture and the time the culture has grown. (See figure 1).





The antibiotics albamycin, bacitracin, celesticetin, neomycin, polymyxin, streptolydigin, and tetracycline were supplied by the courtesy of the Research Laboratories of the Upjohn Company, Kalamazoo, Michigan; and chloromycetin, streptomycin, and viomycin were purchased from Parke Davis and Company. These antibiotics were tested singly and in various combinations. Combinations of antibiotics were made as indicated in Table 1. Whereas Table 1 indicates combinations only, the tests were conducted in various ratios of one antibiotic with the other as recorded in the thesis in the library at Illinois State Normal University.

TABLE 1
ANTIBIOTIC COMBINATIONS MADE

Antibiotics	Viomycin	Tetracyline	Streptomycin	Streptolydigin	Polymyxin	Neomycin	Chloromycetin	Celesticetin	Bacitracin
Albamycin	O[1]	O	O	X	O	O	X	X	X
Bacitracin	X[2]	X	X	X	X	X	X	X	X
Celesticetin	X	X	X	X	X	X	X		
Chloromycetin	X	X	X	X	X	X			
Neomycin	X	X	X	X	X				
Polymyxin	X	X	X	X					
Streptolydigin	X	O	X						
Streptomycin	X	X							
Tetracyline	X								

[1] "O"— antibiotics failed to go into solution.
[2] "X"—designates antibiotic combinations made.

It was found that massive doses of any of the antibiotics used were required to inhibit this organism, a fungus. Areas of complete inhibition of the organism were observed with 100,000 μg/ml. of chloromycetin (1μg (microgram) /ml. is the same as 1/,000,000 gram/milliliter), with 60,000 μg/ml. of neomycin, with 15,000 μg/ml. of tetracycline. In the highest concentration used for each of the following: 100,000 μg/ml. of albamycin, 200,000 μg/ml. of bacitracin, 100,000 μg/ml. of celecticetin, 300,000 μg/ml. of streptomycin, and 300,000 μg/ml. of viomycin only areas of partial inhibition were observed.

It is evident that these were massive dosages when only 1/5 μg/ml. of terramycin, chloromycetin or aureomycin and similar small concentrations of the other antibiotics were sufficient to control bacteria. That these quantities were needed to show any inhibiting action with this organism suggests that perhaps one reason the majority of antibiotics have proven ineffective in the control of fungi is that large enough doses of the antibiotic have not been tried. Practically, though, the use of large doses is limited by the cost, and by the possibility of detrimental effects of high concentrations of the antibiotic on the host plant or animal cells.

The evaluation of the antimicrobial action of antibiotics when used in combination is a complicated task, because the methods of determination, the interpretation of the results, and the significance of the terms vary among the investigators.

The effects that may result when antibiotics are used in combination have been designated as: **synergism, addition, antagonism,** and **indifference.**

Synergism is variously defined as: 1). The enhancement of the activity of one antibiotic by the activity of another so that the combined effects is greater than the sum of the activity of the two separately. 2). Two agents acting together in specific concentrations to produce an effect greater than that which could be achieved by the same quantity of either agent alone. 3). The ability of two antimicrobial drugs acting together to increase markedly the rate of early bactericidal action, as compared with the rate of either drug alone. and to kill greater numbers of bacteria, or to cure experimental or clinical infection more effectively than could be expected from simple algebraic summation of single drug effects. 4). A combined effect of two drugs that is greater than that obtained by doubling the test conconcentration of either drug. 5). A potentiating action in which one drug augments the action of the other on individual cells.

Confused with **synergism** is the effect designated as **additive,** which may be defined as one in which the two drugs together work better than either alone in spite of the fact that they act independently on different members of the microbial population; that is to say each antibiotic varies in effectiveness against particular strains of a species of microorganism so that while one drug inhibits a large proportion of the species population the other drug is effective against

those members of the species resistant to the former as well as some of the strains inhibited by the former. For example, a combination of 1/7 of the dosage of an antibiotic which will kill 99% of a microbial population together with 1/40 of the dosage of a second antibiotic to effect 99% inhibition can produce complete inhibition. It this case the effect may be interpreted as additive in that each antibiotic is effective against that portion of the population which the other is not. Each drug is acting independently.

The third term, **antagonism,** may be defined as 1). a change resulting in a susceptibility equivalent to one-half or less than one-half the original susceptibility, when the agent was used singly. 2). a decrease in the inhibiting activity below that of one or both of its components.

The final term, **indifference,** may be defined as the effect shown by any two antibiotics when acting simultaneously on a microbial population, which is the same as the more active drug alone.

Increased antibiotic activity resulting from the use of the combination of two antibiotics was noted with eleven combinations. The experimental results of these eleven antibiotic combinations when judged on the basis of the first three of the five definitions for synergism showed that all eleven combinations were possibly synergistic, but when the results were evaluated on the basis of the last two definitions only three of the eleven combinations appeared to be synergistic. These three combinations bacitracin and neomycin, tetracycline and celesticetin, and polymyxin were studied further, and a discussion of the results with bacitracin and neomycin illustrates the nature of this work.

Because antibiotic activity has been variously expressed in "units" which vary with the antibiotic and the organism against which the antibiotic is used, there is understandably some confusion in interpreting the actual dose used. Investigators, after the chemical nature of some antibiotics had been determined, attempted to standardize laboratory procedures by expressing antibiotic concentrations in micrograms per milliliter of antibiotic solution. We propose that since the chemical structures of the many antibiotics available is so different and their molecular weights so different that a better interpretation of their activity could be obtained if we considered the number of molecules of antibiotic acting against a fixed population density of the microorganism. Accordingly the concentrations of antibiotics in micrograms per milliliter were converted into micromoles per milliliter by dividing the micrograms of antibiotic used by the molecular weight of the antibiotic used: so an index of the number of molecules of antibiotic acting against uniformly seeded plates of *Ceratostomella ulmi* was obtained because the observations for antibiotic activity were made at 96 hours, a time before which the fungus normally does not sporulate; that is, the colony density is still that with which the plates were seeded.

In all experiments the plates were seeded with 100,000 spores of

Ceratostomella ulmi uniformly distributed in 15 ml. of medium so that for purposes of interpretation an area expressed in square centimeters served as an index to the population of the microorganism. Therefore the areas of the zones of complete inhibition indicated the number of organisms inhibited. If we plot the areas of these zones of complete inhibition against the number of micromoles per milliliter of the antibiotic, or in the case of combinations the sum of micromoles per milliliter of each antibiotic used in the combination, we have a graph of the activity of molecular concentrations against organisms killed. (See Figure 2.)

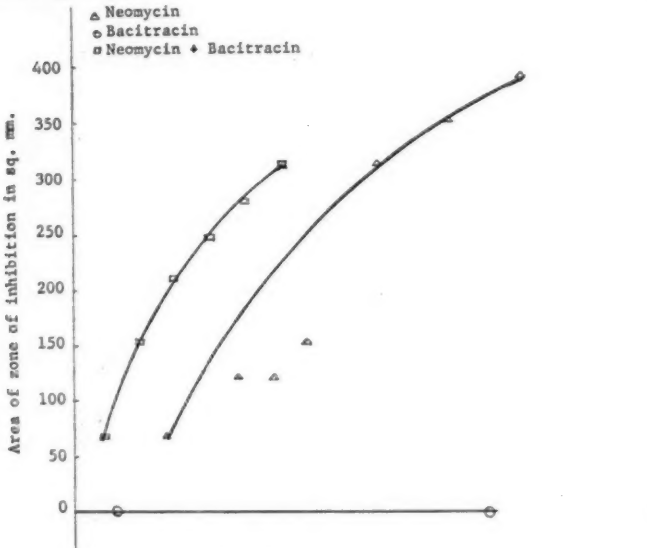


Fig. 2

In Figure 2 we have plotted the areas of zones of complete inhibition against the antibiotic doses expressed in micromoles per milliliter for bacitracin, and neomycin alone and for neomycin and bacitracin combined. For the combination the dosage of bacitracin was fixed at 34.0 micromoles per milliliter, and the neomycin concentration was varied, but the sum of the concentrations was ploted.

For bacitracin it is seen from the figure that the fungus was not inhibited even with the highest concentration used. In the case of neomycin the data indicated that as the concentration of the anti-

biotic is increased the number of cells killed increased but not in direct proportion with the increase in concentration. Where the antibiotic combination is used we can see that at the first point of the curve a concentration of 66 micromoles of drug composed of 34 micromoles of bacitracin and 32 micromoles of neomycin produces an inhibition the same as 77 micromoles of neomycin, and in addition 136 micromoles of bacitracin alone produced no inhibition whatsoever. We interpret this as truly synergistic activity in that surely the action of neomycin has been augmented by the action of bacitracin or that the bacitracin has become effective because of the presence of neomycin.

Another aspect for consideration in interpreting the graph is the change in curvature. We see that with a fixed concentration of bacitracin a small increase in dosage of neomycin triples the number of organisms inhibited but that as the concentration of neomycin in the combination is increased the inhibition also increases but not quite so markedly.

Similar results were obtained with the other two combinations.

In the many combinations made, the results with seven combinations indicated the possibility of **antagonism,** some indicated **indifference,** and the **additive** effect could not be interpreted because a sufficient number of concentrations were not prepared.

These data were assembled from the horizonal diffusion method, and a number of assumptions were made which could introduce a relatively large quantitative error. Zones of complete inhibition only were measured. No attempt was made to include the area of partial inhibition. The degree of purity of the antibiotic was not determined. For the purpose of determining the direction of the study of combinations of antibiotics upon fungi, this may be considered adequate, and more precise quantitative determinations can be made by other methods.

In addition, when the plots were made of the areas of the zone of complete inhibition with respect to the total number of antibiotic molecules in the dose, the assumption that the dose was distributed only in the area of complete inhibition was assumed. This, of course, would introduce the least error only in larger zones of complete inhibition since the volume of fluid added was the same in all cases. For a really accurate comparison by this method we would have to plot total dose versus mole ration of dose, which gives the same zone of inhibition; and this, of course, assumes the coefficient of diffusion of each antibiotic is the same, an assumption itself not very valid when we consider that the difference in the size of molecules varies with the antibiotic.

We may summarize this investigation by noting that large doses of some antibiotics are effective against the fungus *Ceratostomella ulmi* and that some combinations of antibiotics are more effective than when the antibiotics are used singly. We suggest that the interpretation of the action of antibiotics and antibiotics in combination can be more clearly understood if the concentration of antibiotics is expressed in micromoles per milliliter.

THE PREDICTION OF TEACHER SUCCESS IN SECONDARY SCHOOL MATHEMATICS

MYRA ANN STORMER

With improvement of public education being stressed more and more in response to the national and international advances made in science and technology, increasingly greater emphasis is being placed on ability to predict teacher success in American society. The prediction of teacher success in mathematics will enable secondary school officials to staff their schools with the best qualified to meet the demand for better training of pupils in mathematics. It will also enable the curriculum committees of teacher-education institutions to predict more effectively the teaching success of a student, determine areas in which he needs to improve, and adjust the curriculum or programming to provide the kind of prefessional training most needed to improve teaching ability.

In this study a comparsion was made between certain selected variables to determine which ones were significant as predictors of teaching success for graduates of Illinois State Normal University in the field of secondary school mathematics. The variables included grades in student teaching, university grade point averages, and grade point averages in mathematics and education courses. Variables of a second type were obtained from the Kuder Preference Record and included interest scores in the areas of computation, persuasion, and social service. Teaching success was determined by weighting traits on which each mathematics teacher, a graduate of Illinois State Normal University between 1954 and 1958, was rated by his principal at the completion of his first year of teaching.

Principals rated first year teachers above average, average, or below average on fourteen traits or characteristics: personal, character, disposition, mental, scholarship, language, voice, classroom management, techniques of teaching, growth of understanding, teaching results, pupil-teacher relations, community adjustment and professional attitude. These are the traits listed on the present rating sheet used by the University's Placement Bureau. Each trait is accompanied by a brief description of the factors to be evaluated. Because each of the traits does not have equal significance in determining teacher success, each trait was given a numerical weight to give more influence to the factors considered to be the most significant in other studies. For example, teaching results, techniques of teaching, and pupil-teacher relations were given a weight of 4, and such traits as voice were given a weight of 1. The data in Table 1 shows the weighted success rating and the student teaching grade of the 42 graduates used in the present investigation.

TABLE 1

TEACHING SUCCESS RATINGS AND STUDENT TEACHING GRADES ATTAINED BY 42 FIRST YEAR MATHEMATICS TEACHERS

Teacher[1]	Teacher Rating	Student Teacher Grade	Teacher[1]	Teacher Rating	Student Teacher Grade
1	64	A	22	49	A
2	64	A	23	47	A
3	64	A	24	46	B
4	64	A	25	45	A
5	64	A	26	44	B
6	64	C	27	43	A
7	64	A	28	43	A
8	63	A	29	42	B
9	63	A	30	41	B
10	61	A	31	41	A
11	60	B	32	39	B
12	59	A	33	39	B
13	58	A	34	39	B
14	57	A	35	38	A
15	57	B	36	35	A
16	53	B	37	35	A
17	53	B	38	35	B
18	53	A	39	30	B
19	51	A	40	29	B
20	51	B	41	26	A
21	49	B	42[2]	18	A

[1] Teachers are listed from highest to lowest according to their teacher success ratings.

[2] This person was later disqualified because of factors outside the study preventing completion of the first year of teaching.

That student teaching grades cannot be depended upon to predict first-year teaching success in mathematics is readily apparent from the results shown in Table 1. It should be noted, however, that fourteen of the highest rated twenty-one received student teaching grades of A, while only nine of the lowest rated twenty received an A. This means that if a student received a grade of A in student teaching, his chance of being rated in the top half is approximately 60%.

The first-year teachers listed in Table 1 were divided into two groups for purposes of the present study. Those numbered 1 through 15 are considered highly successful, while those numbered 32 through 41 are classified as poor. On the basis of the selected variables indicated above, a comparision was made between the two groups by

making use of Student's t-test. The results of these comparisons are shown in Table 2.

TABLE 2

RESULTS OF T-RATIO TEST BETWEEN SUCCESSFUL AND POOR TEACHERS REGARDING UNIVERSITY GRADE POINT AVERAGES AND KUDER INTEREST SCORES

	Results of t-test	t.10[1]	t.05[2]
Total Grade Point Average	2:51	1.71	2.07
Grade Average in Mathematics Courses	1.85	1.71	2.07
Grade Average in Education Courses	2.65	1.71	2.07
Kuder Social Service Score	2.82	1.71	2.07
Kuder Persuasive Score	0.43	1.71	2.07
Kuder Computational Score	0.43	1.71	2.07

[1] t.10 is the value given for t at the 10 per cent level for 23 degrees of freedom.

[2] t.05 is the value given for t at the 5 per cent level for 23 degrees of freedom.

The data obtained in this study seem to warrant the following conclusions:

1. The relationship between social service interests, as measured by the Kuder Preference Record, and success ratings in teaching mathematics is highly significant.
2. Grade point averages in education courses are very significantly related to teaching success in mathematics.
3. Total grade point averages are significantly related to teaching success in mathematics.
2. The relationship between grades in mathematics courses and success in teaching mathematics is significant at the 10 per cent level.
5. No significant relationship exists between interest in computational and persuasive areas, as measured by the Kuder Preference Record, and success in teaching mathematics.
6. Student teaching grades as assigned at Illinois State Normal University are not very predictive of individual teacher success except as they fit into the total professional preparation of the teacher.

Although a high relationship exists between certain selected variables used in this study, the results have most value when applied to a group of teachers. The results of the present study may be helpful in predicting teaching success, but they should be considered somewhat limited in their scope. More research needs to be done to more clearly define teaching success and to isolate other predictive variables.